Public sector transparency and countries' environmental performance: A nonparametric analysis

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Abstract

Based on the theoretical background of the link between countries' transparency and environmental policy our paper provides empirical evidence for a sample of 68 countries for the time period of 2001-2010. By assuming that countries' transparency levels shape their environmental policy which reflects upon their environmental performance levels, we develop an empirical model for investigating such a relationship. By modifying a conditional directional distance function model, we incorporate on the measurement of countries' environmental performance the effect of their public sector transparency levels. The empirical results indicate that public sector transparency has a statistically significant impact on countries' environmental performance with the relation in the case of emerging-developing economies appearing as an inverted 'W' shape, whereas in the case of advanced-developed economies indicating an inverted 'U' shape.

Keywords: Conditional directional distance function; Corruption perception index; Environmental performance; Nonparametric regression.

JEL classification: C14; D73; H00; Q00; Q50.

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1. Introduction

Corruption is a significant problem of our society and it is spreading across public sector. According to Shleifer and Vishny (1993) bureaucrats are enhanced with the power to manage public properties. If bureaucrats are self interested, they may exploit this power in order to achieve personal gains to the detriment of public interest. This power is referred to as discretionary power (Jain, 2001).

Environment and especially environmental regulations is an area where corruption is a common issue. Environmental regulations are imposed and monitored by bureaucrats who may be corrupted and act for their personal interest (Damania, 2002). According to Bulte et al. (2007) rural subsidies are given to wealthy farmers who either bribe or make political contribution to the officials in order to receive the subsidies. Governments which are more corrupted tend to offer more subsidies to agricultural production and especially wealthy producers against public goods. The authors claim that subsidies are considered as inefficient economic tools for social policy and they are related to low agricultural and land productivity, distortion of the prices and trade, expansion of the rural land and deforestation.

Fredriksson (1997) states that subsidies directed to reduce environmental degradation may result to its increase while Lopez and Galinato (2007) argue that government's subsidies either on public or private goods have a significant effect on economic development. If the government reduces subsidies on private goods, ceteris paribus, it will have a positive effect on rural per capita income and it will reduce poverty and environmental degradation. Corruption can lead to environmental degradation in terms of land conversion and as result deforestation (Barbier et al., 2005). The lower agricultural yields are the greater deforestation will be because farmers need more agricultural land to produce the same level of output as if the agricultural yields were higher and it is possible for them to convert forest land to serve their purpose (Angelsen, 1999). The author argues that this is true only for poor farmers but Bulte et al. (2007) found that this also stands for wealthy farmers if the government which provides subsidies is corrupted.

A number of scholars point out that economic integration may put pressure on government for less stringent environmental regulations, in favor of the polluting industry and employment (Damania et al., 2003). Industries which are environmentally non-friendly often form a lobby in order to achieve less stringent environmental regulations and avoid the costs of applying new and cleaner technologies (Damania, 2001). A corrupted government favors the creation of these special interest groups whose purpose is to extract policy concessions to serve their interests. Political considerations may lead these industries to reject friendly for the environment investments even if they mean lower production costs (Damania, 2001). According to Fredriksson et al. (2004) there are three aspects that lead to a special interest group's success. Namely, the incentives of the lobby group to offer a bribe, its ability to coordinate bribery and government's willingness to be bribed.

Our paper by following the theoretical models indicating that countries' public corruption levels influence their environmental policies, develops a model in order to provide empirical evidences for such a relationship. Based on the work of Simar and Vanhems (2012) our paper modifies Färe and Grosskopf's (2004) directional distance function model incorporating bad outputs in order to account for the effect of countries public sector corruption levels. More specifically, we propose a conditional directional distance function model with the treatment of bad outputs[1] in productivity analysis, which is conditioned on the effect of countries' public sector transparency levels. As a result we will be able to model the effect of countries' transparency levels on their environmental performance and thus to have a direct measurement of the effect of corruption on countries' environmental policies as has been suggested on the theoretical models by several authors (Damania, 2001, 2002; Damania et al., 2003; Fredriksson and Svensson, 2003; Fredriksson et al., 2003; Fredriksson and Millimet, 2004; Fredriksson et al., 2004).

2. Literature review

Aidt (1998) demonstrate that competition between special interest groups is significant for the internalization of economic externalities, which combines Coasian and Pigouvian approaches to environmental policy. According to the Coasian approach, affected groups will act in accordance with their goals. Rather than protecting their interests via private agreements with high transaction costs, they choose political market to minimize them. According to the Pigouvian approach, a corrupted bureaucrat with discretionary power fulfills the demands of special interest groups to the detriment of public interest. Thus, Aidt (1998) concludes that Coasian and

[1] Färe et al. (1989) were the first who treated pollutant as 'bad' output in a environmental production process by imposing strong and weak disposability.

Pigouvian approaches are connected under the public-choice axiom of political self interest.

Fredriksson and Svensson (2003) develop an environmental policy theory based on corruption and political instability. According to their theory corruption has a negative effect on the stringency of environmental regulations but this effect fade away as political instability increases. This happens because political instability means that the lobby group may bribe the government but the government may not maintain its power enough to implement the desirable regulation. Corruption related to environmental issues is also more commonly found at developing countries where political instability is higher and institutions are weaker, less effective and more corrupted (Lopez and Mitra, 2000).

According to Bimonte (2002) quality of institutions positively affects environmental quality. Damania (2002) points out that in developing countries corruption is considered as one of the main factors of environmental degradation. This is a consequence of the way people confront life. According to Arrow (1995) in poor countries material welfare is more important compared to environmental degradation. Desai (1998) finds empirical evidence for the relationship of environmental degradation and corruption by examining ten developing countries. Lopez and Mitra (2000) provide also evidence that corruption increases pollution levels for any given level of income.

Bulte et al. (2007) examine the case of Latin America, where fifty percent of governments' subsidies are directed to private goods. Among others, they were targeted to selected producers with specific crops and free services were aimed for wealthy users, like irrigation services. These subsidies have caused many problems such as deterioration of development, decrease of productivity, excessive conversion of forest to agricultural land and depletion of natural resources. Barbier et al. (2005) highlight conversion of the forest to agricultural land as the main factor of tropic deforestation in Central America and Amazonia, where the government supports cattle ranching forestry and large-scale agriculture. Meanwhile, in Asia, South America and Africa deforestation is a result of government's support to large scale plantations, timber harvesting and cash crops. The authors state that these policies are also responsible for the depletion of natural resources and loss of biodiversity.

Fredriksson et al. (2004) study the effect of corruption on energy policy. They found three remarkable results which reveal that corruption's effect on energy policy is identical to corruption's effect on environmental policy. First, more corruption of the bureaucrats means less stringent policies. Second, increased coordination costs of the special interest groups means more stringent policies. Third, capital owners and workers have opposite lobbing interests on energy policy.

Damania et al. (2003) investigate the relationship between corruption, trade and environmental policy and their results converge with the results of Fredriksson et al. (2004). To be more specific, more corruption results to less environmental stringency although more trade policy liberalization results to more stringent environmental regulations when the level of corruption is high. According to Fredriksson (1999), in a system of perfect competition, open trade increases the incentives of a special interest group to put pressure on government's decision on environmental policy, when the country has a comparative advantage in the polluting sector.

According to Welsh (2004) corruption affects pollution directly and indirectly. Direct impact refers to the effect of corruption on pollution while indirect influence refers to the effect of corruption on per capita income and the resultant impact on pollution. Cole (2007) applies Welsh's theory of direct and indirect impact in the case of corruption's impact on air pollution. He finds a positive direct impact of corruption on per capita emissions while the indirect impact was found to be larger than the direct but negative. Fredriksson et al. (2003) find direct and indirect impact of corruption acting as an environmental stringency. When more bureaucrats become corrupted environmental policy tends to become less stringent and this is the direct effect. When the level of corruption rises, more bribes tend to be offered. The increased number of bribes tends to lower bribe's price given to each individual and the result of this indirect effect is a more stringent environmental policy.

3. Data and Methodology

3.1 Data

In our study we use a sample of 68 countries[2] for the time period 2001-2010 in order to measure their environmental performance levels. Based on

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[2] Developed Countries (24): Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States of America.
Emerging, Developing Countries (44): Argentina, Azerbaijan, Bangladesh, Bolivia, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Honduras, India, Indonesia, Jordan, Kenya, Latvia, Malaysia, Mauritius, Mexico, Namibia, Nicaragua, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russian Federation, Senegal, South Africa, Thailand, Tunisia, Turkey, Ukraine, Uruguay, Venezuela and Vietnam (IMF Advanced Economies List, 2012, p.179-183).

several other studies similar to ours (Färe et al., 1989, 1996, 2004; Färe and Grosskopf, 2003; Chung et al., 1997; Tyteca, 1996, 1997; Picazo-Tadeo and García-Reche, 2007; Halkos and Tzeremes, 2009) we use two inputs, capital stock[3] and total labour force (in thousands) and two outputs, real GDP (in US Dollars at current prices and current exchange rates in millions)[4] and total CO_2 emissions (in million tones)[5]. Finally our external variable is corruption perception index (CPI)[6] which measures for each country the degree to which public sector's corruption is perceived to exist.

3.2 Measuring countries' environmental performance

Following the model proposed by Färe and Grosskopf (2004) we let $P(x)$ to denote an input vector $x \in \Re_+^N$ which can produce a set of undesirable outputs $u \in \Re_+^K$ (in our case carbon dioxide emissions-CO_2) and desirable outputs $v \in \Re_+^M$ (real GDP). Then in order to determine the environmental technology several assumptions are needed to be taken following Shephard (1970) and Färe and Primont (1995). We assume that the output sets are closed and bounded and that inputs are freely disposal. In addition $P(x)$ can be an environmental output set if:

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[3] We have calculated capital stock by using the perpetual inventory method: $K_t = I_t + (1-\delta)K_{t-1}$ where K_t is countries' gross capital stock in current year; K_{t-1} is the gross capital stock in the previous year; I_t is the gross fixed capital formation and δ represents the depreciation rate of capital stock. In our study, following Zhang et al. (2011), we set δ equal to 6%.

[4] Data of capital formation, total labour force and real GDP were obtained from UNCTAD Statistics: http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx.

[5] Data were obtained from two sources: 1) Carbon Dioxide Information Analysis Center: http://cdiac.ornl.gov and 2) United Nations Statistics Division: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid=.

[6] Many studies (Gokcekus and Knörich, 2006; Gokcekus, 2008; Gundlach and Paldam, 2009; Hanousek and Koćenda, 2011) have used CPI as a proxy of corruption with a scale from 0 (perceived to be highly corrupt) to 10 (perceived to have low levels of corruption). For details see: http://www.transparency.org/policy_research/surveys_indices/gcb.

1. $(v,u) \in P(x)$ and $0 \leq \theta \leq 1$ then $(\theta v, \theta u) \in P(x)$ (i.e. the outputs are weakly disposable) and

2. $(v,u) \in P(x)$, $u = 0$ implies that $v = 0$ (i.e. the null jointness assumption of good and bad outputs).

In order to formalize the environmental technology we use the data envelopment analysis (DEA) framework.

Let $k = 1, \ldots, K$ be the observations and then the environmental output can be formalized as:

$$
\begin{aligned}
P(x) = \Big\{ (v,u) : &\sum_{k=1}^{K} \omega_k v_{km} \geq v_m, m = 1, \ldots, M, \\
&\sum_{k=1}^{K} \omega_k u_{kj} = u_j, j = 1, \ldots, J, \\
&\sum_{k=1}^{K} \omega_k x_{kn} \leq x_n, n = 1, \ldots, N, \\
&\omega_k \geq 0, k = 1, \ldots, K \Big\}
\end{aligned}
\qquad (1)
$$

$\omega_k, k = 1, \ldots, K$ indicate the intensity variables which are not negative and imply constant returns to scale[7]. The inequality on the good outputs and the equality on the bad outputs help us to impose the weak disposability assumption and only strong disposability of good outputs. However the null-jointness is imposed by the following restrictions on bad outputs:

$$
\begin{aligned}
&\textstyle\sum_{k=1}^{K} u_{kj} > 0, j = 1, \ldots, J, \\
&\textstyle\sum_{j=1}^{J} u_{kj} > 0, k = 1, \ldots, K.
\end{aligned}
\qquad (2)
$$

[7]Our environmental efficiency measurement follows the most common assumption made in Economics which is the constant returns to scale (CRS) assumption. In addition the CRS assumption provides us with greater discriminative power among the examined countries.

Furthermore, we apply the directional distance function approach as in Chung et al. (1997) to be able to reduce bad and expand good outputs[8]. In order to be able to model that in the directional distance function setting we use a direction vector $g = (g_v, -g_u)$, where $g_v = 1$ and $-g_u = -1$. Then the efficiency score for a country k' can be obtained from:

$$\begin{aligned} &D\left(x^{k'}, v^{k'}, u^{k'}; g\right) = \max \beta \\ &s.t.\left(v^{k'} + \beta g_v, u^{k'} - \beta g_u\right) \in P(x) \end{aligned} \tag{3}$$

In this way, the linear programming problem can be calculated as:

$$\begin{aligned} &D\left(x^{k'}, v^{k'}, u^{k'}; g\right) = \max \beta \\ &s.t. \quad \sum_{k=1}^{K} \omega_k v_{km} \geq v_{k'm} + \beta g_{vm}, m = 1, \ldots, M, \\ &\qquad \sum_{k=1}^{K} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1, \ldots, J, \\ &\qquad \sum_{k=1}^{K} \omega_k x_{kn} \leq x_{k'n} \\ &\qquad \omega_k \geq 0, k = 1, \ldots, K. \end{aligned} \tag{4}$$

Efficiency is next indicated when $D\left(x^{k'}, v^{k'}, u^{k'}; g\right) = 0$ and inefficiency by $D\left(x^{k'}, v^{k'}, u^{k'}; g\right) > 0$. Due to the fact that we are using the efficiency scores derived in a second stage analysis we present the efficiency scores obtained in terms of Shephard's output distance function. In fact according to Chung et al. (1997) Shephard's output distance function is a special case of the directional distance function and can be calculated as:

$$D(x, v, u) = 1 / \left(1 + D\left(x^k, v^k, u^k; v^k, u^k\right)\right) \tag{5}$$

[8] This is the most common assumption made for directional distance functions when measuring environmental efficiency levels.

3.3 Conditional directional distance functions incorporating bad outputs

In the principles of Daraio and Simar (2005, 2006, 2007) who extent the probabilistic formulation of the production process firstly introduced by Cazals et al. (2002), let the joint probability measure of $\left(X, Y^{v,u}\right)$ and the joint probability function of $H_{XY^{v,u}}(.,.)$ be defined as[9]:

$$H_{XY^{v,u}}\left(x, y^{v,u}\right) = \text{Prob}\left(X \leq x, Y^{v,u} \geq y^{v,u}\right) \tag{6}$$

Moreover the following decomposition can be obtained as:

$$H_{XY^{v,u}}\left(x, y^{v,u}\right) = \text{Prob}\left(Y^{v,u} \geq y^{v,u} \middle| X \leq x\right) \text{Prob}\left(X \leq x\right) = S_{Y^{v,u}|X}\left(y^{v,u} \middle| x\right) F_X(x) \tag{7}$$

where $F_X(x) = \text{Prob}(X \leq x)$ and $S_{Y^{v,u}|X}\left(y^{v,u} \middle| x\right) = \text{Prob}\left(Y^{v,u} \geq y^{v,u} \middle| X \leq x\right)$.

Additionally, let $Z \in R^r$ denote the exogenous factors to the production process (in our case is countries' transparency levels). Then equation (6) becomes:

$$H_{XY^{v,u}|Z}\left(x, y^{v,u} \middle| z\right) = \text{Prob}\left(X \leq x, Y^{v,u} \geq y^{v,u} \middle| Z = z\right) \tag{8}$$

which completely characterizes the production process.

According to Daraio and Simar (2005) the following decomposition can be derived:

$$\begin{aligned} H_{XY^{v,u}|Z}\left(x, y^{v,u} \middle| z\right) &= \text{Prob}\left(Y^{v,u} \geq y^{v,u} \middle| X \leq x, Z = z\right) \text{Prob}\left(X \leq x \middle| z\right) \\ &= S_{Y^{v,u}|X,Z}\left(y^{v,u} \middle| x, z\right) F_{X|Z}\left(x \middle| z\right) \end{aligned} \tag{9}$$

The estimator of the conditional survival function introduced above can be obtained from:

[9] For simplicity of presentation, $Y^{v,u}$ symbolizes both bad (u) and good (v) outputs.

$$\hat{S}_{Y^{v,u}|X,Z}\left(y^{v,u}\middle|x,z\right)=\frac{\sum_{i=1}^{n}I\left(Y_i^{v,u}\geq y^{v,u},X_i\leq x\right)K_h\left(Z_i,z\right)}{\sum_{i=1}^{n}I\left(X_i\leq x\right)K_h\left(Z_i,z\right)} \tag{10}$$

where $K_h\left(Z_i,z\right)=h^{-1}K\left(\left(Z_i-z\right)/h\right)$ with $K(.)$ being a univariate kernel defined on a compact support (Epanechnikov in our case) and h is the appropriate bandwidth calculated following Bădin et al. (2010)[10].

Recently Simar and Vanhems (2012) developed the probabilistic characterization of directional distance function taking the general form of:

$$D\left(x,y;g_x,g_y\right)=\sup\left\{\beta>0\middle|H_{XY}\left(x-\beta g_x,y+\beta g_y\right)>0\right\} \tag{11}$$

and the conditional directional distance function of (x,y) conditional on $Z=z$ can then be defined as:

$$D\left(x,y;g_x,g_y\middle|z\right)=\sup\left\{\beta>0\middle|H_{XY|Z}\left(x-\beta g_x,y+\beta g_y\middle|Z=z\right)>0\right\} \tag{12}$$

Based on these developments the probabilistic form of Färe and Grosskopf 's (2004) model (presented previously) measuring country's environmental performance will take respectively the form of:

$$D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\right)=\sup\left\{\beta>0\middle|H_{XY^{v,u}}\left(x^{k'},v^{k'}+\beta g_v,u^{k'}-\beta g_u\right)>0\right\} \tag{13}$$

In addition the conditional form of the model in (13) will take the form of:

$$D\left(x^{k'},v^{k'},u^{k'};g_v,g_u\middle|z\right)=\sup\left\{\beta>0\middle|H_{XY^{v,u}|Z}\left(x^{k'},v^{k'}+\beta g_v,u^{k'}-\beta g_u\middle|Z=z\right)>0\right\} \tag{14}$$

Finally, the DEA program for the environmental performance score for a country k' when using the conditional output oriented directional distance function can be calculated as:

[10] The calculation of bandwidth by Bădin et al. (2010) is based on the Least Squares Cross Validation (LSCV) criterion introduced by Hall et al. (2004) and Li and Racine (2007).

$$D\left(x^{k'}, v^{k'}, u^{k'}; g_v, g_u \middle| z\right) = \max \beta$$

$$\begin{aligned}
s.t. \quad & \sum_{\substack{k=1,\ldots,K| \\ |Z_k - z| \le h}} \omega_k v_{km} \ge v_{k'm} + \beta g_{vm}, m = 1,\ldots, M, \\
& \sum_{\substack{k=1,\ldots,K| \\ |Z_k - z| \le h}} \omega_k u_{kj} = u_{k'j} - \beta g_{uj}, j = 1,\ldots, J, \\
& \sum_{\substack{k=1,\ldots,K| \\ |Z_k - z| \le h}} \omega_k x_{kn} \le x_{k'n} \\
& \omega_k \ge 0, k = 1,\ldots, K \text{ such that } |Z_k - z| \le h.
\end{aligned} \tag{15}$$

3.4 Determining the effect of countries' public sector transparency levels

In order to identify the effect of countries' public sector transparency levels[11] on the obtained environmental performance levels without specifying in prior any functional relationship, our paper applies a nonparametric regression. Following, Li and Racine (2007) and Racine (2008) let us have a random variable X (countries' public sector corruption levels) with a probability density function (PDF) $f(x)$. Then the Gaussian kernel $K(x)$ can be defined as:

$$K(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2} \tag{16}$$

and the PDF of $f(x)$ can be obtained from:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right) \tag{17}$$

where h represents the bandwidth calculated by the least squares cross-validation data driven method as suggested by Hall et al. (2004).

[11] Transparency is the inverse of corruption. Transparency in government is often credited with generating government accountability. Transparency often allows citizens of a democracy to control their government, reducing government corruption, bribery and other malfeasance (Frederick, 2011, pp. 1346-1350).

In addition let us have the variable Y to denote countries' conditional environmental performance $[D\left(x^{k'},v^{k'},u^{k'};g_v,g_u \middle| z\right)]$[12]. The joint PDF of (X,Y) can be defined as:

$$\hat{f}(x,y)=\frac{1}{nh_xh_y}\sum_{i=1}^{n}K\left(\frac{X_i-x}{h_x}\right)K\left(\frac{Y_i-y}{h_y}\right) \tag{18}$$

where (h_x,h_y) are representing the bandwidths calculated by the least squares cross-validation data driven method and $K(.)$ represents the Gaussian kernel defined previously.

The conditional PDF between the two variables accordingly can be obtained from:

$$\hat{g}(y|x)=\hat{f}(x,y)/\hat{f}(x) \tag{19}$$

Then our nonparametric regression will have the general form of:

$$Y=g(X)+u \tag{20}$$

but as we don't know the functional form of $g(.)$ we will estimate it nonparametrically using kernel methods. In order to obtain the estimation we will need to interpret $g(x)$ as the conditional mean of Y given X.

If we let Y and X be the dependent and independent variables accordingly

(Y = Conditional Environmental Efficiency levels, X = Transparency levels)

following the proof from Li and Racine (2007, p. 59), $g(x)\equiv E\left(Y \middle| X=x\right)$ then

[12] It has been shown from Jeong et al. (2010) that the efficiency estimates are consistent (i.e., estimate the true inefficiency). Moreover they have a fast rate of convergence and also the exogenous variable (i.e. countries' transparency levels) is assumed to directly influence the shape of the frontier (i.e., a separability condition is not assumed). Therefore, the obtained efficiency estimates are determined by the inputs, outputs (good and bad) and the exogenous variable (for details see Simar and Wilson, 2007, 2011).

$E(Y|X)$ is the optimal predictor of Y given X. In this way we can estimate $g(x) \equiv E(Y|x)$ by[13]:

$$\hat{g}(x) = \frac{\sum_{i=1}^{n} Y_i K\left(\frac{X_i - x}{h_x}\right)}{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h_x}\right)} \qquad (21).$$

4. Empirical results

Following the related theory (Damania, 2001, 2002; Damania et al., 2003; Fredriksson and Svensson, 2003; Fredriksson et al., 2003; Fredriksson and Millimet, 2004; Fredriksson et al., 2004) we assume that the shape of countries' environmental production frontier is determined by countries' public sector corruption levels and by the inputs/outputs used. As such the efficiency of countries' environmental policies, which are subject to their public sector corruption levels will be reflected on their obtained conditional environmental performance levels.

Table 1 provides the results of the conditional environmental measures for the 68 countries for the time period of 2001-2010. As can be observed the highest efficiency values in average terms are reported for 2004 (0.7322) and for 2007 (0.705), whereas the lowest performance has been observed for 2002 (0.5877) and for 2009 (0.5845). Also the highest standard deviation of countries' environmental performance is reported for 2010 (0.1729).

Figure 1 presents per year analysis of the number of countries having an environmental performance score above the reported average values.

[13] Equation (26) represents the local constant estimator introduced from Nadaraya (1964) and Watson (1964).

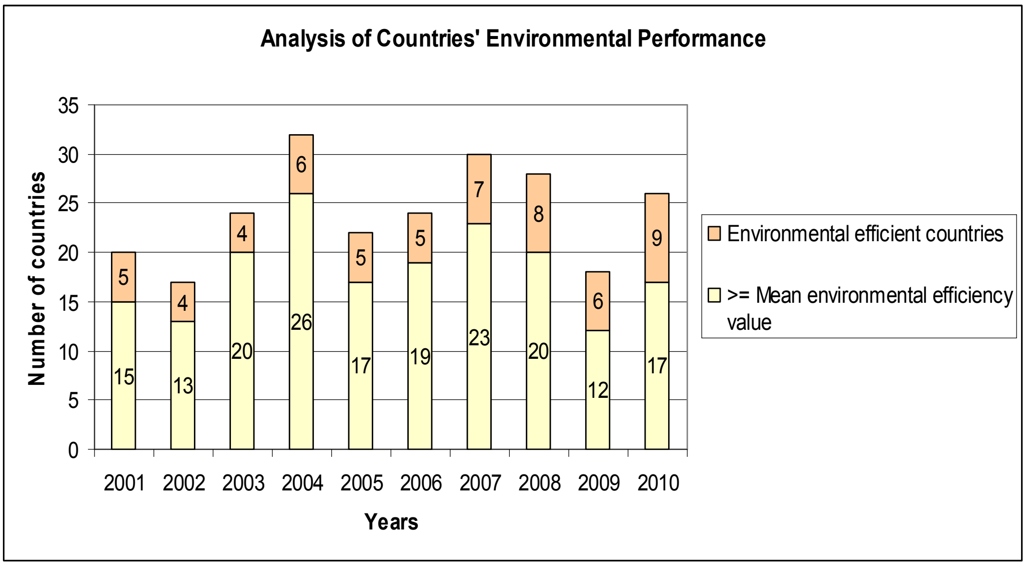
Additionally, it indicates the number of countries being environmentally efficient over the examined time period. For the year 2010 nine countries are reported to be efficient with seventeen countries scoring above the average environmental performance values. It also appears a decrease on the number of countries scoring above average environmental value during the period 2007-2009.

Table 1: Environmental efficiency scores conditional to countries' transparency levels

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Argentina	0.5800	0.5276	0.5498	0.6380	0.5615	0.5719	0.6015	0.6034	0.5257	0.5785
Austria	0.5250	0.5253	0.5476	0.6778	0.5575	0.5688	0.6109	0.5937	0.5150	0.5771
Azerbaijan	0.9567	0.6900	0.6519	0.6373	0.6131	0.6637	0.7521	0.7461	0.5482	0.5415
Bangladesh	0.5500	0.5451	0.5689	0.7060	0.5665	0.5715	0.5937	0.5783	0.5185	0.5167
Belgium	0.5386	0.5444	0.5723	0.6798	0.5875	0.6040	0.6601	0.6722	1.0000	0.6136
Bolivia	1.0000	1.0000	0.5892	0.8571	0.5986	0.6308	0.6811	0.6730	0.5366	0.5346
Botswana	0.5750	0.5676	0.6654	0.6602	0.7201	0.6960	0.7159	0.6626	0.5331	0.5371
Brazil	0.5421	0.5356	0.5570	0.9303	0.5888	0.6179	0.6798	0.6904	0.5466	0.9275
Bulgaria	0.6380	0.6228	0.7377	0.6796	0.7174	0.7363	0.7957	0.7675	0.5510	0.5459
Canada	0.5434	0.5409	0.5713	0.7090	0.5935	0.6136	0.6495	0.6313	0.5323	0.9537
Chile	0.5562	0.5483	0.5820	0.8712	0.6159	0.6530	0.7149	0.6720	0.5220	0.5276
China	0.6076	0.6011	0.6210	0.7357	0.6867	0.7703	0.9791	1.0000	0.6582	0.9269
Colombia	0.5977	0.5813	0.6061	0.6930	0.6360	0.6482	0.7131	0.6811	0.5318	0.5356
Costa Rica	0.5661	0.5625	0.5942	0.7491	0.5953	0.6244	0.6730	0.6449	0.5322	0.5317
Croatia	0.5652	0.5654	0.6141	0.6325	0.6246	0.6408	0.6970	0.6726	0.5310	0.5284
Czech Republic	0.5278	0.5310	0.5555	0.6358	0.5748	0.5938	0.6347	0.6321	0.5252	0.5319
Denmark	0.5259	0.5266	0.5488	0.5822	0.5619	0.5716	0.5971	0.5805	0.5163	0.5672
Dominican Republic	0.5324	0.5312	0.5376	0.7361	0.5643	0.5747	0.6078	0.5918	0.5199	0.5195
Ecuador	0.5720	0.5714	0.6147	0.6136	0.6283	0.6490	0.6874	0.6556	0.5351	0.5305
Egypt	0.5514	0.5436	0.5535	0.5937	0.5643	0.5762	0.6102	0.5946	0.5229	0.5422
El Salvador	0.5270	0.5269	0.5456	0.7223	0.5551	0.5683	0.5935	0.5826	0.5184	0.5183
Estonia	0.5379	0.5402	0.5808	0.6363	0.6111	0.6466	0.7270	0.7070	0.5233	0.5248
Finland	0.5273	0.5283	0.5513	0.8481	0.5634	0.5741	0.6049	0.5892	0.5171	0.5553
France	0.5705	0.5788	0.6255	1.0000	0.6426	0.6665	0.7482	0.7715	0.7026	1.0000
Germany	0.7342	0.7366	0.8408	0.6841	0.8525	0.8714	0.9199	0.8288	0.6295	0.7734
Greece	0.5376	0.5445	0.5653	0.6093	0.5895	0.6014	0.6244	0.6555	0.8325	0.6143
Guatemala	0.5301	0.5312	0.5492	0.5924	0.5635	0.5773	0.6107	0.6006	0.5204	0.5277
Honduras	0.5282	0.5284	0.5483	0.5152	0.5592	0.5755	0.5984	0.5901	0.5263	0.5259
Iceland	0.5023	0.5025	0.5048	0.9245	0.5082	0.5097	0.5155	0.5102	0.5017	0.5025
India	0.6781	0.6722	0.7215	0.7011	1.0000	1.0000	1.0000	1.0000	0.5493	1.0000
Indonesia	0.5541	0.5576	0.5970	0.5990	0.6049	0.6384	0.6929	0.6655	0.5354	0.5908
Ireland	0.5130	0.5147	0.5304	0.8777	0.5421	0.5540	0.5898	0.5758	0.5116	0.5499
Italy	0.5860	0.5855	0.6536	1.0000	0.6745	0.6862	0.7546	0.7470	0.5749	0.8267
Japan	1.0000	1.0000	1.0000	0.6332	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Jordan	0.5373	0.5366	0.5588	0.8390	0.5761	0.5897	0.6137	0.6075	0.5256	0.5258
Kenya	0.6611	0.6382	0.7682	0.7356	0.6146	0.6427	0.6938	0.6550	0.5330	0.5312

Latvia	0.5451	0.5476	0.6079	0.7508	0.6282	0.6593	0.7261	0.7009	0.5377	0.5384
Luxembourg	1.0000	0.5350	0.5687	0.6134	0.5920	0.6120	0.6663	0.6699	1.0000	1.0000
Malaysia	0.5305	0.5306	0.5511	1.0000	0.5605	0.5722	0.6050	0.6027	0.5235	0.5490
Mauritius	1.0000	1.0000	1.0000	0.6609	1.0000	1.0000	1.0000	1.0000	0.5825	0.5990
Mexico	0.5444	0.5430	0.5623	1.0000	0.5739	0.5891	0.6195	0.6138	0.5238	0.6881
Namibia	0.6708	0.6313	0.8411	0.6476	0.8129	0.7990	1.0000	1.0000	1.0000	1.0000
Netherlands	0.5298	0.5362	0.5489	0.6833	0.5626	0.5734	0.5996	0.6118	0.6034	0.7492
New Zealand	0.5383	0.5406	0.5785	0.5639	0.6031	0.6051	0.6497	0.6066	0.5210	0.5257
Nicaragua	0.5176	0.5187	0.5319	0.7852	0.5392	0.5503	0.5682	0.5603	0.5168	0.5178
Norway	0.5576	0.5584	0.5988	0.7041	0.6265	0.6495	0.7016	0.7080	0.5269	0.6049
Pakistan	0.5504	0.5523	0.5899	0.7495	0.6144	0.6359	0.6944	0.6475	0.5381	0.5574
Panama	0.5974	0.5834	0.6233	0.7196	0.6257	0.6407	0.6802	0.6462	0.5293	0.5260
Peru	0.5753	0.5692	0.6024	0.6066	0.6155	0.6355	0.6815	0.6554	0.5286	0.5275
Philippines	0.5316	0.5317	0.5489	0.6664	0.5613	0.5807	0.6234	0.6098	0.5235	0.5258
Poland	0.5483	0.5458	0.5713	0.5616	0.5955	0.6141	0.6722	0.6612	0.5304	0.5844
Portugal	0.5103	0.5110	0.5225	0.7815	0.5282	0.5341	0.5529	0.5410	0.5083	0.5424
Romania	0.5666	0.5800	0.6437	0.9719	0.6995	0.7145	0.8459	0.8407	0.5526	0.5448
Russian Federation	0.6294	0.6465	0.7023	1.0000	0.8048	0.8843	1.0000	1.0000	0.6036	1.0000
Senegal	0.7594	0.7375	1.0000	0.8312	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
South Africa	0.5853	0.5688	0.6385	0.6998	0.6676	0.6773	0.7257	0.6535	0.5305	0.5456
Spain	0.5350	0.5416	0.5671	0.6702	0.5844	0.6022	0.6530	0.6651	0.5563	1.0000
Sweden	0.5333	0.5338	0.5627	0.6519	0.5760	0.5879	0.6174	0.5909	0.5174	0.5626
Switzerland	0.5326	0.5328	0.5564	0.6299	0.5652	0.5740	0.5977	0.5818	0.5206	0.6154
Thailand	0.5363	0.5361	0.5580	0.6506	0.5664	0.5812	0.6172	0.6035	0.5226	0.5562
Tunisia	0.5440	0.5401	0.5691	0.6969	0.5752	0.5828	0.6130	0.5969	0.5192	0.5176
Turkey	0.5371	0.5399	0.5746	0.6740	0.6079	0.6219	0.6804	0.6653	0.5374	0.6303
Ukraine	0.5386	0.5402	0.5702	0.8420	0.6140	0.6497	0.7336	0.7126	0.5297	0.5296
United Kingdom	0.5817	0.5836	0.6373	1.0000	0.6567	0.6805	0.7502	0.7271	0.5543	0.8201
United States	1.0000	1.0000	1.0000	0.7544	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Uruguay	0.6211	0.5721	0.6230	0.6347	0.6607	0.7160	0.8525	0.8679	0.5418	0.5441
Venezuela	0.5576	0.5385	0.5511	0.6643	0.5815	0.6032	0.6440	0.6428	0.5404	0.5809
Vietnam	0.5620	0.5560	0.5836	0.9886	0.5884	0.6006	0.6268	0.6131	0.5234	0.5199
Mean	0.6021	0.5877	0.6201	0.7322	0.6383	0.6560	0.7050	0.6916	0.5845	0.6417
Max	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Min	0.5023	0.5025	0.5048	0.5152	0.5082	0.5097	0.5155	0.5102	0.5017	0.5025
Std	0.1317	0.1140	0.1159	0.1296	0.1202	0.1191	0.1284	0.1314	0.1390	0.1729

Figure 1: Descriptive analysis of countries' environmental performance conditional to their public sector transparency levels for the period 2001-2010.



In order to quantify if the effect of corruption has significant influence on countries' environmental efficiency levels over the years we apply the nonparametric test for equality of distributions between the obtained efficiency scores. Li et al. (2009) created a test for equality of two density or two conditional density functions defined over mixed discrete or continuous data. By using least squares cross-validation techniques for smoothing parameters they illustrate how to use bootstrap methods for obtaining the statistic's null distribution in finite-sample setting.

Table 2 illustrates the results obtained following the test of equality. According to the test the null hypothesis suggests that the distributions under consideration are equal. As can be observed the results indicate that the conditional to countries' corruption levels environmental efficiency scores are having in the majority of the cases unequal distributions over the examined years.

Table 2: Consistent density equality test for conditional environmental efficiency scores

Years	2002	2003	2004	2005	2006	2007	2008	2009	2010
2001	1.479	4.521***	23.964***	10.715***	15.267***	23.167***	19.976***	0.232**	0.250
2002		6.749***	23.419***	13.574***	16.389***	24.167***	21.294***	-1.063**	-0.345*
2003			15.434***	0.662	4.155***	13.206***	10.796***	16.391***	8.008***
2004				12.402***	6.832***	0.497	3.264**	35.662***	23.630***
2005					0.451	6.592***	5.593**	25.186***	13.327***
2006						3.537**	1.765*	29.941***	17.449***
2007							1.717	35.220***	22.501***
2008								30.383***	18.892***
2009									4.059

*** p-value < 0.001., ** p-value < 0.05; * p-value < 0.1

However, we cannot reject the null hypothesis in six cases (when comparing the efficiencies between 2001-2002, 2003-2005, 2004-2007, 2005-2006, 2007-2008 and for 2009-2010). In any case the results reveal that during the examined periods variations of countries' environmental performance levels have been occurred which are subject to countries' corruption levels variations over the years (since we are looking at the conditional efficiency estimates).

Moreover, in contrast to table 1 we split our original sample according to IMF Advanced Economies List (2012) into countries forming a sample of advanced/developed economies (24 countries in our case) and into a sample formed by countries from emerging/developing economies (44 countries). Thus we conduct an analysis comparing countries' conditional to their transparency levels environmental performances $\left(EP|Z\right)$ from the same development stage. Analysing first the advanced-developed economies (table 3) we realise that over the years the countries with the highest positive percentage change on their EP are Spain (87%), and Canada (75%) whereas two countries are reported to have a negative EP change over the examined period (Estonia and New Zealand).

Similarly table 4 presents the results for the emerging-developing economies. The highest positive EP percentage changes are reported for Brazil (71%), Russian Federation (58%) and China (52%). However and in contrast with the previous sample (advanced-developed economies) more countries are reported to have a negative percentage change over the years with the highest negative changes to be reported for Bolivia (-46%), Azerbaijan (-43%) and Mauritius (-40%).

Having calculated countries' conditional environmental performances we assume that their transparency levels directly influence the shape of their environmental production frontier (therefore the separability condition is not assumed). In this way we can analyse the influence of countries' public sector transparency levels as has been argued in our theoretical model in a second stage nonparametric regression analysis.

Following Racine (2008) we treat countries' $EP|Z$ and their transparency levels as continues variables in a nonparametric regression analysis based upon least squares cross validation (LSCV) criterion for bandwidth selection[14]. Figure 2 presents the results obtained from our nonparametric second stage analysis. Specifically, subfigure 2a presents the underlined relationship for all countries under examination regardless their economic development level. As can be realized for transparency values

[14] In addition a bootstrap consistent significance test for continuous regressors introduced by Racine (1997) and Li and Racine (2007) was applied in order to test the significance of countries' public sector transparency levels on their obtained environmental performances. The obtained p-values indicated that transparency is significant at the conventional 5% level for all the samples of our analysis.

between 0 and 2 we observe a positive effect of transparency indicated by an increasing regression line and a positive derivative.

Table 3: Average environmental performance values and percentage performance changes for Advanced –Developed Economies

Advanced-Developed Economies (24 countries)		
Countries	*Average* EP|Z *(2001-2010)*	EP|Z *percentage change (2001-2010)*
Austria	0.5699	9.9238
Belgium	0.6473	13.9250
Canada	0.6339	75.5061
Czech Republic	0.5743	0.7768
Denmark	0.5578	7.8532
Estonia	0.6035	-2.4354
Finland	0.5859	5.3101
France	0.7306	75.2848
Germany	0.7871	5.3391
Greece	0.6174	14.2671
Iceland	0.5482	0.0398
Ireland	0.5759	7.1930
Italy	0.7089	41.0751
Japan	0.9633	0.0000
Luxembourg	0.7257	0.0000
Netherlands	0.5998	41.4119
New Zealand	0.5733	-2.3407
Norway	0.6236	8.4828
Portugal	0.5532	6.2904
Spain	0.6375	86.9159
Sweden	0.5734	5.4941
Switzerland	0.5706	15.5464
United Kingdom	0.6992	40.9833
United States	0.9754	0.0000
Mean	0.6515	19.0351
Max	0.9754	86.9159
Min	0.5482	-2.4354
Std	0.1172	26.6789

Table 4: Average environmental performance values and percentage performance changes for Emerging –Developing Economies

Emerging -Developing Economies (44 countries)		
Countries	*Average* EP|Z *(2001-2010)*	EP|Z *percentage change (2001-2010)*
Argentina	0.5738	-0.2586
Azerbaijan	0.6801	-43.3992
Bangladesh	0.5715	-6.0545
Bolivia	0.7101	-46.5400
Botswana	0.6333	-6.5913
Brazil	0.6616	71.0939

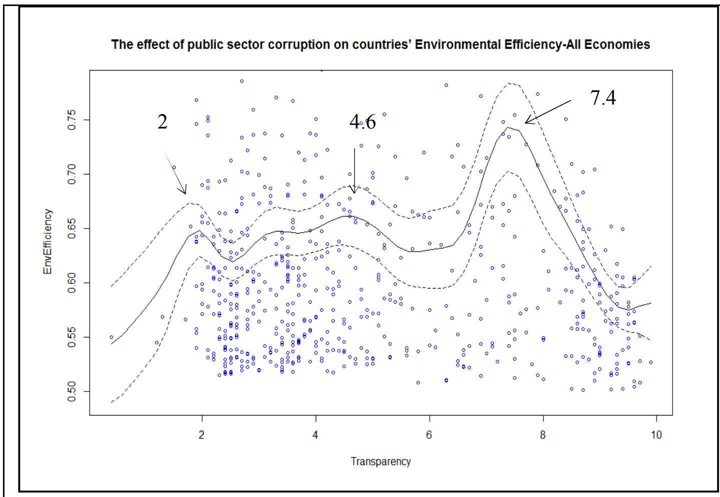
Bulgaria	0.6792	-14.4357
Chile	0.6263	-5.1420
China	0.7587	52.5510
Colombia	0.6224	-10.3898
Costa Rica	0.6073	-6.0767
Croatia	0.6072	-6.5110
Dominican Republic	0.5715	-2.4230
Ecuador	0.6058	-7.2552
Egypt	0.5653	-1.6685
El Salvador	0.5658	-1.6509
Guatemala	0.5603	-0.4527
Honduras	0.5496	-0.4354
India	0.8322	47.4709
Indonesia	0.6036	6.6234
Jordan	0.5910	-2.1403
Kenya	0.6473	-19.6491
Latvia	0.6242	-1.2291
Malaysia	0.6025	3.4873
Mauritius	0.8842	-40.1000
Mexico	0.6258	26.3960
Namibia	0.8403	49.0757
Nicaragua	0.5606	0.0386
Pakistan	0.6130	1.2718
Panama	0.6172	-11.9518
Peru	0.5998	-8.3087
Philippines	0.5703	-1.0910
Poland	0.5885	6.5840
Romania	0.6960	-3.8475
Russian Federation	0.8271	58.8815
Senegal	0.9328	31.6829
South Africa	0.6293	-6.7828
Thailand	0.5728	3.7106
Tunisia	0.5755	-4.8529
Turkey	0.6069	17.3524
Ukraine	0.6260	-1.6710
Uruguay	0.6634	-12.3974
Venezuela	0.5904	4.1786
Vietnam	0.6162	-7.4911
Mean	0.6429	2.2637
Max	0.9328	71.0939
Min	0.5496	-46.5400
Std	0.0918	24.1023

However after that point we have a small decrease and again for a large part we have an increasing regression line up to a certain transparency level (4.6). After that point again we observe a decreasing regression line (negative derivative) and then after a certain level of countries' transparency (6) we observe an increasing regression line indicating a positive effect on environmental performance.

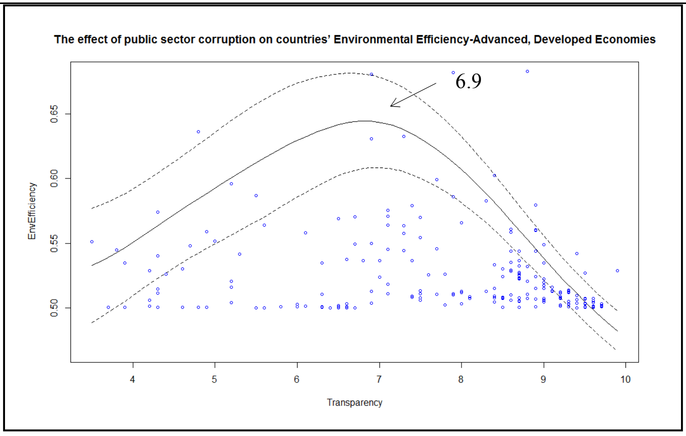
A final turning point is reported at 7.4 countries' public sector transparency level whereas after that point and with larger values of countries public sector transparency levels we have a decreasing regression with negative derivative indicating that the effect is negative. As can be realized we have mixed effects of countries' transparency levels due to the fact that the sample contains countries on different development stages. However, we can conclude that our empirical findings support the theoretical models suggested by several authors indicating a nonlinear relationship between countries' corruption levels and environmental quality.

Similarly, subfigure 2b presents the findings for the sample of the advanced-developed countries. As can be realized for a large part of the range of the transparency levels we have a positive influence indicated by an increasing regression line and a positive derivative up to a certain turning point (6.9). After that we have a decreasing regression line indicating a negative effect. As can be observed for the advanced and developed economies we have an indication of an inverted "U" shape relationship between their public sector transparency levels and their obtained environmental performance levels. Finally, subfigure 2c indicates an inverted "W" shape relationship for emerging and developing countries with two distinct turning points (1.9 and 3.6). As can be realized the empirical findings from our nonparametric analysis indicate a nonlinear relationship between environmental performance and public sector transparency levels.

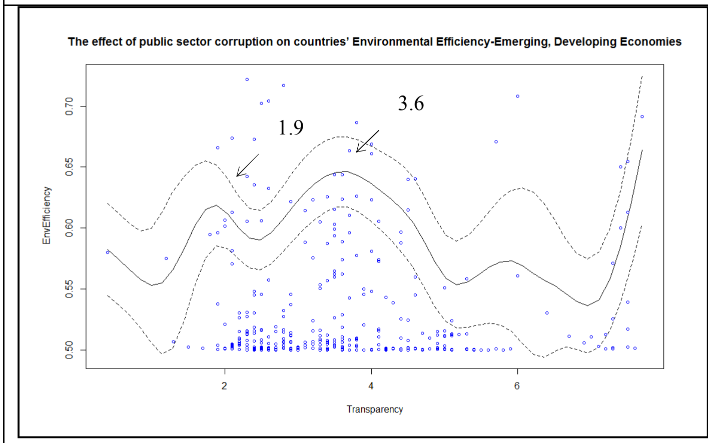
Figure 2: The effect of public sector transparency levels on countries' environmental performance



2a



2b



2c

5. Conclusions

Our paper proposes an empirical model investigating the relationship between countries' public sector transparency levels and their environmental performance in carbon dioxide emissions. In an empirical nonparametric setting our paper extents the model by Färe and Grosskopf (2004) and by using the conditional directional distance measures as introduced by Simar and Vanhems (2012) develops a conditional directional distance model measuring countries' environmental performance under the effect of countries' public sector transparency levels.

In a second stage of a nonparametric regression analysis, our results reveal an inverted 'U' shape relationship between advanced and developed countries' environmental performance and public sector transparency levels. However in the case of emerging-developing countries the relationship between countries' environmental performance and their public sector transparency reveals an inverted 'W' shape.

Our empirical findings provide evidence for several other studies (Damania, 2001, 2002; Damania et al., 2003; Fredriksson and Svensson, 2003; Fredriksson et al., 2003; Fredriksson and Millimet, 2004; Fredriksson et al., 2004) investigating the relationship between countries' environmental policy and public corruption levels.

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